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MRI evaluation of accuracy of arthroscopic anatomical single bundle ACL reconstruction using hamstring graft

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Abstract

Purpose: This study was aimed to determine the accuracy of arthroscopic anatomic single bundle anterior cruciate ligament (ACL) reconstruction using MRI at one year postoperatively.

Patients and Methods: This prospective study included 40 patients (34 males and 06 females) who underwent arthroscopic anatomic single bundle ACL reconstruction with hamstring tendon autograft using medial portal technique. The patients were evaluated at one year postoperatively by clinical examination and MRI. The MR images were evaluated for graft location, tunnel location, graft signal intensity, graft quality, and graft ligamentization.

Results: The ACL was found to be anatomically reconstructed in 37 (92.5%) cases. The mean sagittal inclination angle of ACL graft was 54 degrees (range 48.6°- 60°). The mean coronal inclination angle of ACL graft was 70.5 degrees. The mean center of tibial tunnel was found to be at 42.6% of AP diameter of tibia (range 35-51%). The mean femoral graft angle (FGA) was 50.5 degrees (range 43.5°-57°). The graft ligamentization was present in 38 (95%) cases.

Conclusion: Single bundle ACL reconstruction using medial portal technique results in anatomical location of the graft. MRI is an excellent tool to evaluate the graft and bone tunnel location, graft signal intensity, and graft ligamentization.

Keywords: Anatomical, ACL reconstruction, MRI evaluation

1. Introduction

ACL reconstruction is one of the most commonly performed sports medicine procedures in the United States, with more than 130,000 procedures performed each year [1]. Anatomic placement of ACL graft is critical to the success and clinical outcome of ACL reconstruction. Anatomic ACL graft placement is defined as positioning the ACL femoral and tibial bone tunnels at the center of the native ACL femoral and tibial attachment sites. In the anatomical SB technique, the femoral tunnel is first drilled to the center of the anatomical attachment of the native ACL at the medial wall of the lateral femoral condyle using AM portal [2, 3, 4]. Then the tibial tunnel is drilled at the center of anatomic tibial native ACL insertion with a guide and the graft is fixed with the knee at 15-20º of flexion [5]. Clinical evaluation and conventional radiography are used in routine follow up after ACL reconstruction. However, as clinical manifestations of graft complications are often nonspecific, and plain radiographs cannot directly visualize the graft and the adjacent soft tissues, an important tool in the evaluation of ACL reconstructed knee has been magnetic resonance imaging (MRI) [6]. The MRI appearance of an asymptomatic ACL-reconstructed knee varies depending upon graft type, fixation technique, and time interval after surgery [7, 8].

2. Patients and Methods

This study was a prospective study conducted from September 2015 to March 2018, after approval of the institutional board. The study included 40 cases: 34 males and 06 females, aged between 18-45 years. Informed consent was obtained from all the cases. Arthroscopic anatomic single bundle ACL reconstruction was performed using quadrupled hamstring tendon auto graft. In addition to standard antero medial (AM) and anterolateral (AL) portals, accessory antero medial (AAM) portal was used for femoral tunnel placement.

This portal was made to allow improved visualization of the lateral wall of the inter condylar notch and achieve anatomical placement of the femoral tunnel. All patients followed a post-ACL reconstruction rehabilitation protocol. In our patients, the follow up protocol was at 1week, 2 weeks, 4 weeks, 6 weeks, 12 weeks, 4 months, 6 months, 9 months and final follow up at one year. Final evaluation of patients was done at one year postoperatively based on MRI, stability tests (manual Lachman and pivot shift tests), and Lysholm score. All MR images were evaluated by an experienced radiologist.

3. Results

3.1 Graft Inclination Angle

Using Illingworth technique, the inclination angle of ACL grafts in our patients was 48.6°-60°. The mean inclination angle was 54°.

38 (95%) cases had inclination angle within the normal anatomical range of 43° to 57°.

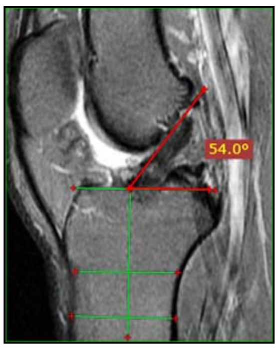

Fig 1: Sagittal MR image showing inclination angle of ACL graft equal to 54 degrees.

The coronal graft inclination was calculated as the angle between the tangent line to the tibial plateau and the line which best defines the course of the intra-articular part of the graft. The mean coronal inclination angle of ACL graft in our cases was 70.5°.

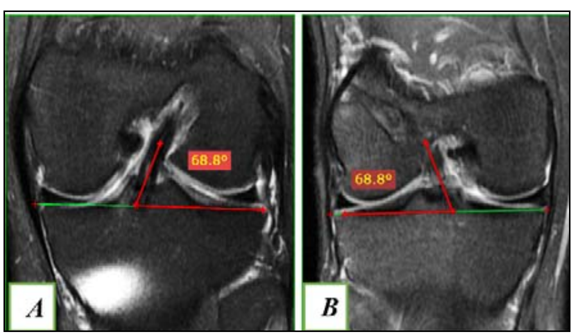

Fig 2 (a) and (b): Coronal MR images showing coronal inclination angle of 68.8 degrees.

3.2 Graft Ligamentization

Graft ligamentization at the intra-articular portion of graft was assessed by evaluating the signal intensity of the graft and the integration of the graft on the tibial side as described by Figueroa *et al*. [9] the graft integration at the level of the tibial tunnel was evaluated by the presence or absence of synovial fluid at the tunnel-graft interface.

MRI signal intensity of the ACL grafts was low in 20 (50%) patients, intermediate in 18 (45%) patients, and high in 1 (2.5%) patient. In one patient, graft was invisible and signal intensity was not available.

Presence of synovial fluid at the graft tunnel interface was observed in 4 (10%) cases.

In our study, Figueroa score was between3-5 in 38 (95%) cases, indicating good ligamentization.

The MR appearance of the ACL grafts was catagorised into 3 types on the basis of signal intensity and continuity of the ligament, according to Rak's method [10].

- **Well defined type:** the graft was visualized as smooth, continuous band with low intensity over the entire course. This type of graft was observed in 21 (52.5%) cases.
- **Intermediate type:** Signal intensity increased and a low signal band was visualized only in part of the graft. This type of graft was observed in 17 (42.5%) cases.
- **Indiscernible type:** the graft was not identified through the joint cavity due to markedly increased signal intensity. This type of graft was seen in 1 (2.5%) case. In one patient graft was not visible on MRI.

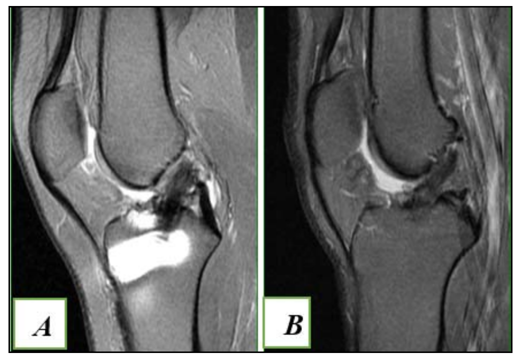

Fig 3 (a) and (b): Sagittal MR images 12 months after ACL reconstruction shows the absence of synovial fluid at the bone–tendon graft interface and a hypointense signal of the intra-articular portion of the graft, indicating good ligamentization of ACL graft. (Well defined type grafts).

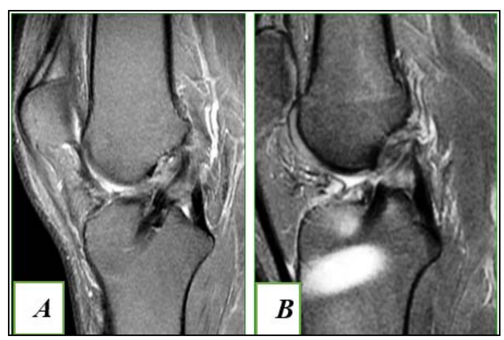

Fig 4 (a) and (b): Sagittal MR images 12 months after ACL reconstruction showing intermediate signal intensity within the graft substance due to graft revascularization. (Intermediate type grafts).

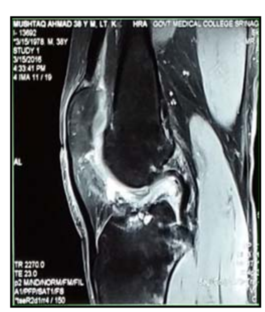

Fig 5: Sagittal MR image of a 38-year-old male 13 months after ACL reconstruction showing hyperintense signal of the graft indicating poor ligamentization. (Indiscernible type graft).

3.3 Tunnel Findings

3.3.1 Tibia Tunnel: On sagittal images, the center of the tibial tunnel was measured as the percentage of the maximum anteroposterior (AP) diameter of tibia. The center of tibial tunnel was at 35-38% of the AP diameter in 2 (5%) cases, 39-46% of AP diameter in 37 (92.5%) cases, and 47-51% of AP diameter in 1 (2.5%) case. The mean center of tibial tunnel was at 42.6% of AP diameter of tibia. In 37 (92.5%) cases, the center of tibial tunnel was within the normal range of 39-46%.

Fig 6: The maximum AP diameter of the tibia (AB) was measured. The distances from the anterior margin of the tibia to the center of tibial tunnel insertion site (CD) was measured. The center of tibial tunnel was measured as the percentage of the maximum AP diameter of tibia. (CD/AB × 100).

On coronal images, the maximum lateral-to-medial (L-M) diameter of the tibia was measured and the distance from the lateral side of the tibia to the center of the tibial tunnel was measured.

On coronal images, the center of tibial tunnel was found at 46%-55% of the LM tibial width, with a mean of 51.7%.

Fig 7: The maximum lateral-to-medial (L-M) diameter of the tibia (EF) and the distance from the lateral side of the tibia to the center of the tibial insertion (GH) was measured. The center of tibial tunnel was measured as the percentage of the maximum L-M diameter of tibia.

Table 1: Tibial tunnel location in relation to Blumensaat's line

Location of tibial tunnel	Number of patients	Percentage
Posterior and parallel to Blumensaat line	37	92.5
Anterior to Blumensaat line	02	5
Posterior and non-parallel	01	2.5

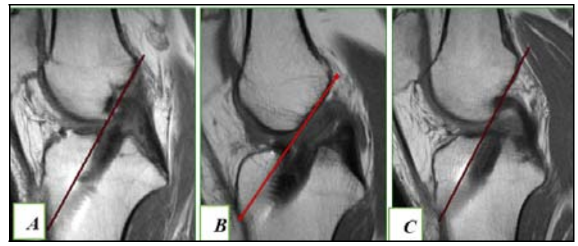

Fig 8 (a) (b) (c): Sagittal MR images 12 months after ACL reconstruction showing tibial tunnel location posterior and parallel to the Blumensatt's line within normal anatomic position.

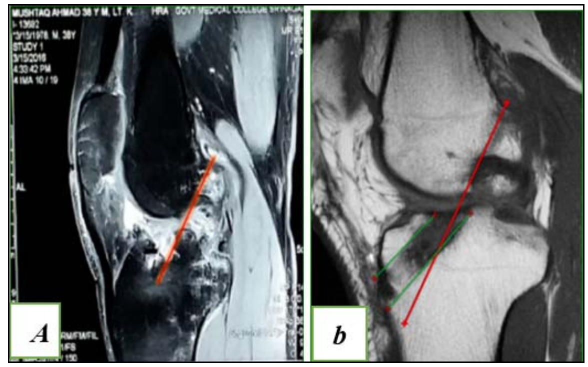

Fig 9 (a) (b): Sagittal images showing tibial tunnel location anterior to Blumensatt's line, outside the normal anatomic position.

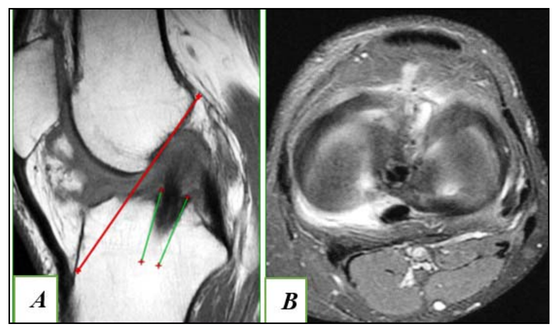

Fig 10 (a) (b): Tibial tunnel located non-parallel to the Blumensaat's line on saggital image (a), and far posterior on axial image (b).

3.3.2 Graft impingement

Graft impingement was evaluated as the tibial tunnel being placed partially or completely anterior to the most anterior edge of the femoral notch roof, corresponding to the Blumensaat line [6]. The graft impingement was seen in 2 patients.

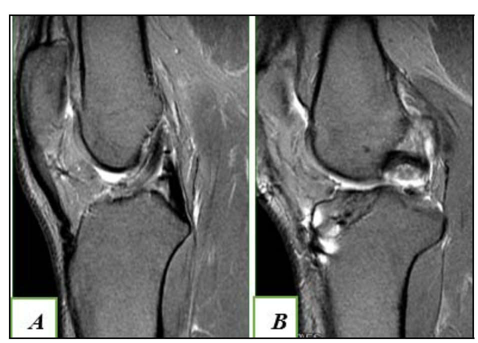

Fig 11 (a) (b): Sagittal images 12 months after ACL reconstruction showing graft impingement, due to anterior location of tibial tunnel. Note the increased signal intensity in distal portion of graft.

3.3.3 Femoral Tunnel
Obliquity of femoral tunnel in the coronal plane was calculated by the femoral graft angle (FGA). The FGA was defined as the angle between the axis of the femoral tunnel and the joint line [11]. The mean FGA was 50.5 degrees (range 43.5-57 degrees).

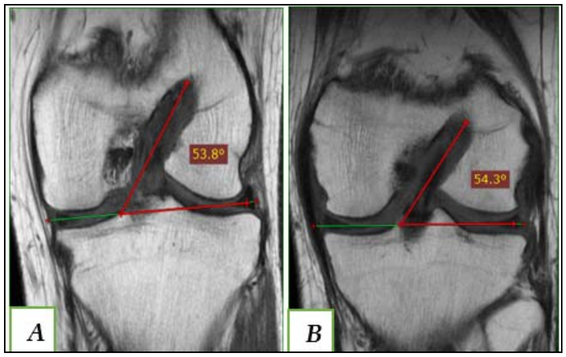

Fig 12 (a) (b): Coronal images showing obliquity of femoral tunnel using femoral graft angle.

Table 2: Post-Operative MRI evaluation

S.No.	Femoral Tunnel Location on MR Images		Tibial Tunnel Location on MR Images	Femoral Tunnel Obliquity	Graft Type on MRI	MRI Graft Signal Intensity	Ligamentization		
	Sagittal Inclination	Coronal Inclination	% of the AP depth	% of the LM tibia width	Femoral graft angle (FGA)		Synovial fluid at graft tunnel interface	Figueroa's Score	ligamentization
1	54.9°	73.6°	46%	55%	49.1°	Well defined type	Low	Absent	3+2 = 5	Good
2	55.9°	73.4°	46.40%	52%	49°	Intermediate type	Intermediate	Absent	2+2=4	Good
3	49°	70°	42.80%	53.50%	48°	Intermediate type	Intermediate	Absent	2+2=4	Good
4	54°	68°	39%	55%	57°	Well defined type	Low	Absent	3+2=5	Good
5	54.8°	72.9°	42%	53%	45.3°	Well defined type	Low	Absent	3+2=5	Good
6	52°	65.5°	37%	55%	48°	Indiscernible type	High	Present	1+1=2	Insufficient
7	49.7°	67.6°	42%	54%	43.5°	Well defined type	Low	Absent	3+2=5	Good
8	53.9°	73.9°	46%	55%	47.7°	Intermediate type	Intermediate	Absent	2+2=4	Good
9	48.6°	73.3°	41%	52%	46.2°	Intermediate type	Intermediate	Absent	2+2=4	Good
10	60.26°	71°	50.90%	50%	54.3°	Well defined type	Low	Absent	3+2=5	Good
11	56°	70.5°	42.60%	52%	53°	Well defined type	Low	Absent	3+2=5	Good
12	53.8°	82.5°	40.50%	54%	56.1°	Intermediate type	Intermediate	Present	2+1=3	Good
13	50.8°	68.6°	40.80%	52.30%	52°	Intermediate type	Intermediate	Absent	2+2=4	Good
14	56.4°	62.8°	45%	53.40%	48.4°	Intermediate type	Intermediate	Absent	2+2=4	Good
15	51.48°	65.31°	44.20%	53.20%	48.6°	Intermediate type	Intermediate	Absent	2+2=4	Good
16	58.16°	70.1°	45.80%	51%	50.3°	Well defined type	Low	Absent	3+2=5	Good
17	NA	NA	41%	51%	45.4°	NA	Not available	NA	NA	NA
18	52°	70.5°	42.60%	50%	51°	Well definetype	Low	Absent	3+ 2 =5	Good
19	56°	73°	45.40%	54.60%	54°	Well defined type	Low	Absent	3+2=5	Good
20	57.6°	73.6°	39%	51.60%	47.5°	Intermediate type	Intermediate	Present	2+1=3	Good
21	54°	68°	43%	51%	50°	Intermediate type	Intermediate	Absent	2+2 =4	Good
22	56.18°	71.8°	44%	50%	46.9°	Well defined type	Low	Absent	3+2=5	Good
23	56°	73.8°	35%	51.20%	56.6°	Well defined type	Low	Absent	3+2=5	Good
24	53°	63°	41%	51%	57°	Well defined type	Low	Absent	3+2=5	Good
25	54°	72°	42.60%	49%	50°	Well defined type	Low	Absent	3+2=5	Good
26	54°	73.3°	41%	50.20%	50°	Intermediate type	Intermediate	Absent	2+2=4	Good
27	53°	68°	42.60%	49.20%	53.4°	Well defined type	Intermediate	Absent	2+2=4	Good
28	54.9°	70.5°	39.60%	52%	52°	Intermediate type	Low	Absent	3+2=5	Good
29	58.2°	72.6	40.60%	50%	51°	Intermediate type	Intermediate	Absent	2+2=4	Good
30	55°	67.3°	43.70%	50.40%	47°	Well defined type	Intermediate	Absent	2+2=4	Good
31	56.5°	68°	44.70%	52.50%	51.6°	Well defined type	Low	Absent	3+2=5	Good
32	55.8°	70°	42.80%	52.20%	50°	Intermediate type	Low	Absent	3+2=5	Good
33	53.1°	67.3°	43.60%	50.60%	51.5°	Well defined type	Low	Absent	3+2=5	Good
34	50°	70°	44%	50%	53.4°	Intermediate type	Intermediate	Absent	2+2=4	Good
35	58°	74°	41.50%	50.20%	52.4°	Well defined type	Low	Absent	3+2=5	Good
36	52.2°	70°	42.60%	50.40%	47.6°	Intermediate type	Intermediate	Absent	2+2=4	Good
37	51.5°	72°	42.85%	50.60%	51.2°	Well defined type	Intermediate	Present	2+1=3	Good
38	54°	73.6°	42%	50%	53°	Intermediate type	Low	Absent	3+2=5	Good
39	49.8°	71°	45%	52%	48.6°	Well defined type	Intermediate	Absent	2+2=4	Good
40	58.2°	67.6°	42.40%	51%	51.6°	Well defined type	Low	Absent	3+2=5	Good
Average	54.1°	70.5°	42.60%	51.70%	50.5°					

4. Discussion
The inclination of the native ACL ranges from 43° to 57° and this has been used as the anatomical range of the graft angle, too (12). Using Illingworth technique, the inclination angle of ACL grafts in our patients ranged from 48.6° - 60°. 95% cases had inclination angle within the normal anatomical range of 43° to 57°. The mean coronal inclination angle of ACL graft in our patients was 70.5 °. A coronal ACL angle less than 75°

has been described in the literature as optimal [13]. In a study by Ahn *et al*. [14], the mean coronal angle of native ACL was reported to be 65.9 º ± 4.4 º. Magarelli *et al*. [15] reported the mean coronal ACL angle of 72.5°±5.5°in his stable knees.

The position of the tibial insertion of the ACL in relation to the sagittal AP depth of the tibia, has been determined to be in the range of 39-46% (16). In our study, the mean position of tibial insertion of ACL was 42.6% of AP depth of tibia, which was comparable with other published studies.

Table 3: Comparison of location of tibial insertion of ACL with published studies

Study	No. of knees studied	Anterior–Posterior %	Medial–Lateral %
Tsukada [17] *et al*. (2008)	25	43.9	48.9
Lorenz [18] *et al*. (2009)	12	42.5	49
Sadoghi [19] *et al*. (2012)	30	41	49
Lee [20] *et al*. (2014)	15	39.5	50.6
Parkinson [21] *et al*. (2015)	76	39	48
Present study	40	42.6	51.7

Hantes *et al*. [11] compared the graft obliquity in the coronal plane between reconstructed knees with the transtibial technique (TT) (with a mean FGA of 72º) and AM portal technique (with a mean FGA of 53º) and concluded that the AM portal technique in ACL reconstruction results in a significantly more oblique femoral tunnel in the coronal plane in comparison to the TT technique. The mean FGA in our study was 50.5 º (range 40º -58 º).

According to MRI findings in our patients, the grafts were categorized as well defined type in 21 (52.5%) cases, intermediate type in 17 (42.5%) cases and as indiscernible type in 1 case as per Rak's method. In our study intermediate signal intensity with a low signal band in some portion of graft was found in the grafts of 17 (42.5%) cases. It has been reported that signal intensity of clinically stable ACL grafts increases up to 12 months after surgery and then decreases over the subsequent 12 months [22]. This increase has been attributed to revascularization and cellular infiltration (23) and has been considered an indeterminate finding in the assessment of graft integrity [24]. In our patients, the increased graft SI was not associated with any knee laxity at 1-year follow-up.

5. Conclusion

Single bundle ACL reconstruction using medial portal technique results in anatomical location of the graft. MRI is an excellent tool to evaluate the graft and bone tunnel location, graft signal intensity, and graft ligamentization.

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